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DEVELOPMENT OF A FRAMEWORK FOR THE FOOD AVAILABILITY INDEX FOR RICE CULTIVATION IN PENINSULAR MALAYSIA

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Abstract

Food security is of utmost importance for various reasons, such as ensuring economic stability, national security, and the well-being of the population. In this regard, food security remains a frequently discussed topic in Malaysia, particularly rice being the national staple food and a strategic commodity under various governmental policies related to the agricultural sector. Food availability, as one of the dimensions of food security, plays a fundamental role in indicating the supply of food within the country. Hence, this paper develops a framework for the Food Availability Index (FAI) specifically for rice, aiming to assess food availability of rice throughout the states in Peninsular Malaysia for amplifying food security. The framework was developed by comparing the Global Food Security Index (GFSI) and the UK Food Security Assessment, selecting relevant components and indicators that are appropriate within the context of Malaysia. From the framework produced, the index for the eleven (11) states of Peninsular Malaysia has been calculated by using a composite index according to the scoring given based on data gained from the Department of Agriculture and PLAN Malaysia. The findings indicate that Perak and Pulau Pinang achieved the highest FAI scores of 29. Spatial mapping has also been produced to understand the disparities between rice production within the states in Peninsular Malaysia. The results reveal significant variation among states, with certain regions demonstrating high dependence on external supply sources, posing potential risks to their food security resilience. The study contributes a practical and replicable index framework for state-level food availability assessment, providing useful insights for policy formulation, resource allocation, and long-term national food planning.

Keywords: Agriculture, Food Availability Index, rice supply, food security, spatial mapping

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INTRODUCTION

Rice is a staple food for most Asian countries, including Malaysia. According to Zulkifli et al. (2025) and Das et al. (2020), the region of Asia-Pacific produces and consumes over 90% of the world's rice, which highlights that rice plays a vital role in ensuring food security not only in Malaysia but also in the Asia-Pacific region. However, Malaysia’s self-sufficiency ratio (SSR) of rice in 2023 is at 62.6%, which indicates that this country still has a high reliance on imported rice and exposes its vulnerability towards global market fluctuation, climate change, and domestic production challenges (Dorairaj & Govender, 2023).

Malaysia's rice supply faces significant challenges, including limited arable land, competition from urban development, dependency on imports, and climate-related threats. These factors collectively hinder the country's goal of achieving self-sufficiency in rice production. According to Arshad et al. (2011), agricultural land specifically for rice cultivation has been increasingly encroached by urbanization and industrial development which causes land for rice farming is shrinking over the years. Herath et al. (2019) mention that paddy production in Malaysia, especially the temperature rising phenomenon has reduced the national rice production by 7% and rainfall affecting the production of Kedah state as the rice bowl of Malaysia, by 0.371%.

In this regard, this paper addresses the performance of the states within Peninsular Malaysia in rice cultivation based on selected components and indicators. The objective of this paper is (i) to identify the relevant key components and indicators for the food availability dimension of food security in Malaysia; (ii) to produce a model of the Food Availability Index (FAI); and (iii) to assess the index of food availability of rice in Malaysia to recognize gaps in food production. The outcome of this paper is not only a framework of FAI but also a comparison between states' indices for FAI in rice.

LITERATURE REVIEW

Conceptualizing Food Security and Food Availability

Food security has been defined by various researcher over the years but fundamentally being defined by the Food and Agricultural Organisation (FAO) during the 1996 World Summit as a state where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This definition has then evolved by various researchers by adding more elements that is vital in ensuring food security for a nation. The original definition has set food security as a global concern on the food development that emphasis on few aspects not only the availability but also the access, safety and the nutritional adequacy (Stashkevych, 2024). Clap et al. (2022) indicate that based on the definition, dimensions of food security though Global Food Security Index (GFSI) has been introduced which are availability, access, utilization, and stability. The FAO Food

Security Policy Brief (2006) lays out the four-pillar food security conceptualization framework, as follows:

- Food availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports and including food aid.
- Food access: Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet.
- Utilisation: Utilisation of food through adequate diet, clean water, sanitation and healthcare to reach a state of nutritional wellbeing where all physiological needs are met.
- Stability: To be food secure, a population, household or individual must have access to adequate food at all times without risking losing access to food as a consequence of sudden shocks.

Food Security has been further discussed as a global concern when Sustainable Development Goals (SDGs) also mention food security as one of the keys to sustainability through the second goal which is zero hunger. SDG 2 aims to end hunger, achieve food security, and improve nutrition while promoting sustainable agriculture by 2030. It focuses on ensuring universal access to safe, nutritious, and sufficient food for all, especially vulnerable populations (United Nations, 2015).

While the world is focusing on the food security, an inverse concept of it which is food insecurity has also actively being discussed. Food insecurity has been defined by Furey (2025) as the inability to afford or access a healthy diet which is further recognized as a public health emergency with significant implications for businesses, households, and civic society. In ensuring a nation achieves a desired food security, four pillars of food security have been assessed and monitored globally by using Global Food Security Index (GFSI). The first dimension is food availability which shows availability or agricultural productivity is the main vital components without disregarding the other three (3) pillars. According to Mohamed (2023), food availability is indeed a crucial pillar of food security, as it ensures that food is reliably accessible daily. Without consistent availability, individuals cannot achieve food security, highlighting its fundamental role in the overall framework.

Global Food Security Index (GFSI)

The Global Food Security Index (GFSI) is a composite indicator developed by the Economist Intelligence Unit to monitor food security progress at the country level, covering over 100 countries since 2012 (Izraelov & Silber, 2019). This index has been published annually for all 113 participating countries. Based on the GFSI in 2022, Finland has been ranked first with an overall score of 83.7.

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According to Niemi et al. (2023), Finland able to be ranked first in GFSI because of this country have a strong natural resource and climate resilience, including abundant clean water, low vulnerability to climate change, and robust policies for sustainable land use. On the other hand, Syria has been ranked in the last place with the total score of 36.3. The primary reason Syria ranks last in the Global Food Security Index (GFSI) is the severe degradation of its agricultural sector, primarily due to prolonged conflict and climate change. The civil war has devastated agricultural infrastructure, leading to a 75% decline in wheat production, while drought-like conditions and high fuel costs have further exacerbated food insecurity (World Food Programme, 2023).

The GFSI Availability component incorporates a diverse set of eight indicators: access to agricultural inputs, agricultural R&D, farm infrastructure, volatility of agricultural production, food loss, supply chain infrastructure, sufficiency of supply, and political/social barriers as shown in Figure 1. These indicators reflect not only production levels but also the systems that ensure food reaches consumers efficiently and equitably. For instance, supply chain infrastructure includes cold chains, storage facilities, and transportation networks are the main factors affecting food loss and timely availability.

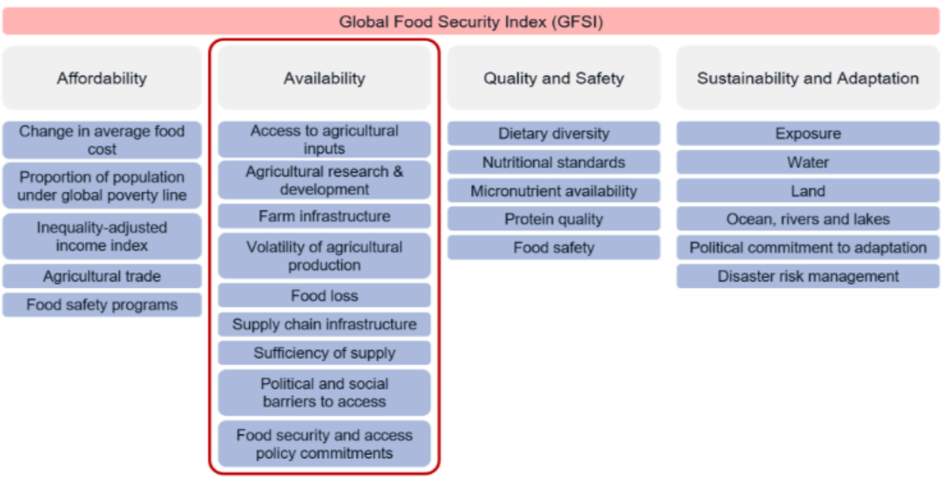

Figure 1: Framework of Global Food Security Index (GFSI)

The GFSI also provides insight into national-level performance. For Malaysia, GFSI scores show mixed progress: while affordability has improved significantly, availability has seen minimal gains over the past several years. This emphasizes the importance of enhancing domestic production and resilience in distribution systems which shows Malaysia is prioritising modernisation through sustainable practices and technological innovations (Asmawi et al., 2025).

UK Food Security Assessment Framework

The UK Food Security Assessment offers another robust framework, structured around four pillars: Availability, Food Chain Resilience, Household Food Security, and Safety and Confidence (Figure 2). It integrates both domestic and global indicators to assess the nation's food resilience, particularly in the wake of Brexit and the COVID-19 pandemic. Within the availability pillar, the UK framework measures dimensions such as the EU's share of imports, diversity of fruit and vegetable supply, and port infrastructure flexibility.

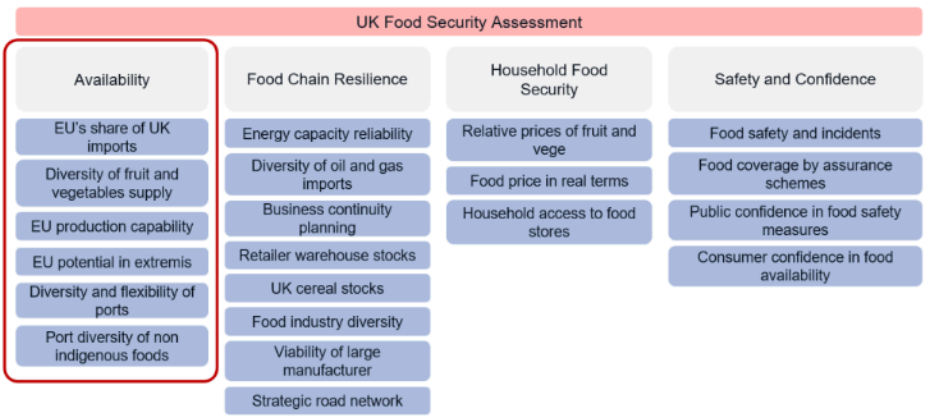

Figure 2: Framework of The UK Food Security Assessment

These indicators reflect how trade dependencies, import routes, and infrastructural diversity shape the availability of food across the UK. The framework's emphasis on port diversity and supply chain redundancy highlights a recognition that physical availability is not just about production but about distribution capacity and logistical resilience. This multidimensional approach aligns with global standards set by the FAO and is particularly useful for understanding systemic vulnerabilities and opportunities for strengthening food system infrastructure.

Insights on Food Losses, Infrastructure and Land Use

Extensive literature reinforces the relevance of the FAI indicators. Food loss remains a critical factor in food availability; global studies estimate cereal losses at 20–30%, and even higher for fruits and vegetables. In Malaysia, post-harvest losses for rice and vegetables can reach up to 50%, especially in rural states with limited infrastructure (MOA, 2021; Shamsudin & Selamat, 2012). Similarly, research on mechanization shows that the use of agricultural machinery can significantly reduce labor dependency and increase productivity. However,

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disparities exist between states, with urban areas showing higher machinery penetration and rural states relying more on manual labour.

Land use is another crucial aspect. While certain states like Perlis and Kedah exhibit high paddy land usage efficiency, others face urban encroachment or underutilization of designated agricultural parcels. Spatial planning and zoning policies, such as those under PLANMalaysia's KaGuMN initiative, play a pivotal role in maintaining land for food production.

RESEARCH METHODOLOGY

The Formulated Food Availability Index (FAI) Framework for Rice in Peninsular Malaysia

Building on the strengths of the GFSI and UK frameworks, this study formulates a localized national Food Availability Index (FAI) designed to assess rice availability across the eleven states in Peninsular Malaysia. Unlike broader international models, the FAI is specifically tailored to Malaysia's agricultural context, particularly for its staple food.

Based on models from the UK and globally, as well as the context of the agricultural sector in the country, the study developed a national FAI. The FAI framework includes four pillars and eight indicators (Figure 3). Agricultural Production being measured by average yield of cleaned paddy and total paddy production, capturing the efficiency and volume of rice cultivation at the state level. Land Use Proportion Indicators include planted area and the percentage of paddy parcels planted, reflecting land allocation and utilization efficiency. Supply infrastructure assess the road networks and levels of mechanization across six stages of production (land preparation, sowing, manuring, spraying, and harvesting). Food losses represented by post-harvest losses, which remain a significant challenge in the Malaysian agricultural supply chain. Each indicator is assessed through both quantitative and spatial methods, producing a composite score that enables state-level comparisons and categorization into low, medium, and high availability zones.

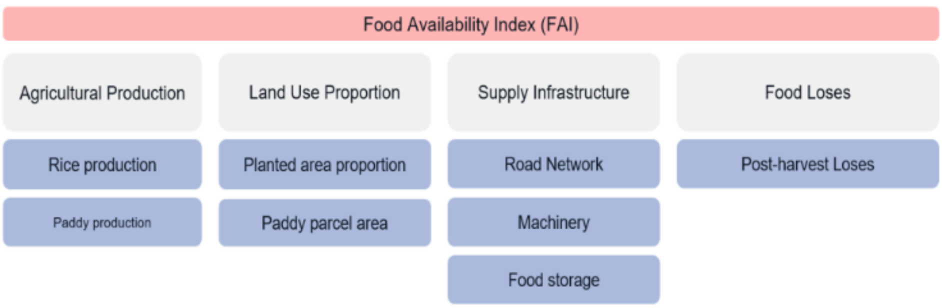

Figure 3: Framework of Food Availability Index (FAI) for Rice

Methods of Data Collection and Data Analysis
This study conducts quantitative research, which employed an expert validation method as its primary data collection technique, supplemented with secondary data obtained from authoritative government sources including the Department of Agriculture (DoA) and PLANMalaysia (Table 1). The research aimed to construct a localized and composite FAI that measures and monitors local rice availability.

Table 1 FAI Indicator Code and List

Component	Indicator Code	Indicator (Unit)
Agricultural Production	FAI 1.1	Average yield of cleaned paddy (Kilogram per Hectare)
	FAI 1.2	Paddy production (Metric Tons)
Land Use Proportion	FAI 2.1	Planted area for paddy (Ha)
	FAI 2.2	Percentage for paddy parcel and paddy planted (%)
Supply Infrastructure	FAI 3.1	Road Network (Rank)
	FAI 3.2	Machinery usage in land preparation (%)
	FAI 3.3	Machinery usage in sowing (%)
	FAI 3.4	Machinery usage in manuring (%)
	FAI 3.5	Machinery in chemical spraying (%)
	FAI 3.6	Machinery usage in harvesting (%)
Food Losses	FAI 4.1	Post-Harvest Looses (%)

To create the composite index, the data was normalized using Min-Max normalization to standardize measurements across different units. Each indicator in its component was given equal weight based on expert consensus obtained through the expert validation method. Two experts from Public Works and Ladang Perlating Jerneh, specializing in agriculture and infrastructure, were consulted to validate the final FAI output. The component scores were then combined to generate a composite FAI score for each state. The results were classified into three availability levels: low, medium, and high based on their composite scores. Spatial analysis was also conducted to visualize the distribution of FAI values across the eleven states, in addition to statistical processing.

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ANALYSIS AND DISCUSSION

Table 2 shows the detailed FAI for rice in eleven states of Peninsular Malaysia using a set of sub-components capturing different dimensions of food availability. Perak and Pulau Pinang had the highest FAI scores of 29, which corresponded to an FAI percentage of 87.9%. Both states scored consistently 3 in almost all the sub-components, reflecting a robust agricultural system, good infrastructure, and minimal food losses.

Table 2: Ranking of Composite FAI for the states in Peninsular Malaysia.

Sub-component	Perak	Pulau Pinang	Kedah	Perlis	Selangor	Pahang	Negeri Sembilan	Kelantan	Terengganu	Johor	Melaka
Agricultural Production	1	3	2	2	2	2	1	2	2	2	1
	3	2	3	3	2	1	1	3	1	1	1
Land Use Proportion	3	2	3	3	2	1	1	3	2	1	1
	3	3	3	3	3	1	1	1	1	1	3
Supply Infrastructure	3	3	1	1	3	2	2	1	1	3	2
	3	3	3	3	3	3	3	2	3	3	2
	3	2	3	3	1	3	3	2	3	3	2
	3	3	3	3	3	3	3	2	2	1	2
	3	3	3	3	3	3	3	2	2	1	2
	3	3	3	3	3	3	3	2	3	3	3
Food Losses	1	2	1	1	2	2	3	2	1	2	1
FAI Level	High	High	High	High	High	High	High	Medium	Medium	Medium	Medium
FAI Score	29	29	28	28	27	24	24	22	21	21	20
FAI Percentage	87.9	87.9	84.8	84.8	81.8	72.7	72.2	66.7	63.6	63.6	60.6
FAI Ranking	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th

Negeri Sembilan and Pahang also scored a "High" level of FAI with 24 points and percentage scores greater than 72%. Though not as good as the first-order states, their performance shows equitable contribution by all the sub-components. The two states significantly outperformed in the supply infrastructure category, indicating that they possessed a steady support system for rice availability.

On the other hand, Johor, Melaka, Terengganu, and Kelantan were categorized under "Medium" FAI, with 20 to 22 scores and 60.6% to 66.7% percentages. These states generally had lower agricultural output and land use proportion scores, which might indicate less emphasis on rice cultivation or less available resources for its growth. The relatively lower infrastructure and moderate food loss levels also contributed to their medium ranking. For example, Johor and Melaka poorer performed in terms of agriculture output as well as wastages in food, and these are areas that need improvement.

Agricultural Production

In terms of agricultural production, the states of Pulau Pinang, Kedah, Perlis, and Kelantan achieved the highest performance with a composite agricultural production percentage of 83.3%. Pulau Pinang, in particular, recorded the highest average yield of cleaned paddy at 5,655.5 kg per hectare, indicating superior productivity despite limited land availability.

Perak, although having a relatively lower yield of 3,260.5 kg per hectare, produced the highest total volume of paddy with total of 244,397 metric tons due to its extensive paddy cultivation area. In contrast, Negeri Sembilan and Melaka recorded the lowest agricultural production scores, mainly attributed to both low yield and small-scale paddy cultivation. Other states such as Pahang, Johor, and Terengganu also fell short in this category with production volumes under 100,000 metric tons per year, raising concerns about their contribution to national rice self-sufficiency (SSR).

Land Use Proportion

Regarding land use proportion, the findings showed that Perak, Kedah, and Perlis achieved perfect scores, indicating both large paddy cultivation areas (exceeding 30,000 hectares) and high land utilization efficiency (over 90% of paddy parcels actively planted). Kelantan, while possessing a large area of paddy land (40,333 hectares), demonstrated relatively low land utilization at 77%, suggesting underutilization of available resources.

States such as Johor, Pahang, and Negeri Sembilan were the weakest in this component, each with less than 10,000 hectares of paddy land and less than 80% land usage. On the other hand, urbanized states like Selangor and Pulau Pinang, despite land constraints, showed strong land efficiency, likely due to integrated zoning policies and optimized land use planning.

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Supply Infrastructure

The third component, supply infrastructure, showed that Perak led with a perfect score, reflecting full mechanization in all farming stages and excellent road network connectivity. Pulau Pinang, Pahang, and Negeri Sembilan also performed well, each scoring 94.4%, indicating that these states are highly equipped to support rice cultivation and distribution. Conversely, Kelantan and Melaka lagged in this component due to limited adoption of agricultural machinery and weaker logistics.

Notably, Selangor scored poorly in the sowing phase (22.2%) because of a strategic transition to transplanter technology, highlighting an evolution toward modern practices rather than a decline in performance. States with strong road infrastructure, such as Selangor, Perak, Johor, and Pulau Pinang, benefit from enhanced inter-state logistics and efficient market access, reinforcing their advantage in rice supply chains.

Food Losses

Food losses, measured through post-harvest unfilled grains, revealed that Negeri Sembilan performed best with the lowest loss (5%) and the highest index score in this category. States such as Pulau Pinang, Selangor, Kelantan, Pahang, and Johor experienced moderate losses between 5.1% and 10%, indicating areas for potential improvement through better harvesting techniques and input management. In contrast, Perak, Kedah, Perlis, Melaka, and Terengganu showed losses above 10%, which is concerning, especially for large-scale producers like Perak and Kedah. These high loss rates may be attributed to a lack of skilled labor, suboptimal post-harvest handling, or inadequate infrastructure, such as drying and storage facilities.

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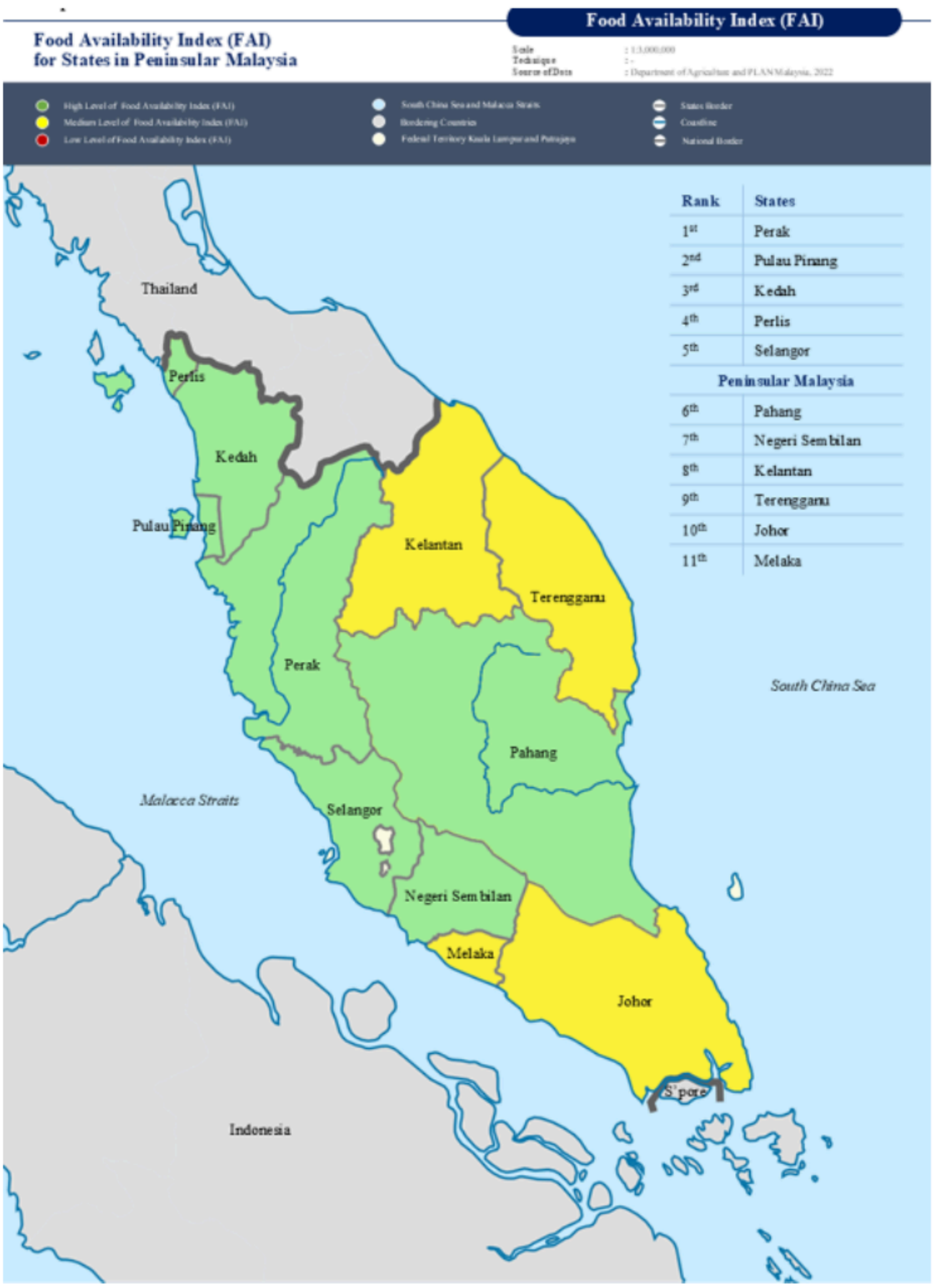

Figure 4: Mapping Result for Food Availability Index (FAI) for Eleven (11) States

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Figure 5: Mapping Result for Food Availability Index (FAI) for Peninsular Malaysia

The results of the Food Availability Index (FAI) analysis indicate that Peninsular Malaysia as a whole achieves a high FAI level (25 scores) for rice, yet this status hovers just slightly above the moderate threshold, signalling that the region is performing satisfactorily but not optimally. Malaysia is also facing issues on underutilised land and traditional method used caused unoptimized yield.

This dual challenge of low land utilisation and reliance on traditional methods is a key barrier to improving national rice self-sufficiency. It signals the need for both technical and policy interventions to revitalise underperforming regions. States like Pahang, Johor, and Negeri Sembilan, in particular, present significant untapped potential for increased rice production if supported with proper incentives, infrastructure, and land use protection mechanisms.

CONCLUSION

The analysis reveals clear spatial disparities in rice availability across the country. Perak and Pulau Pinang emerged as the top-performing states, achieving the highest FAI scores. These states demonstrated strong performance in terms of yield, mechanization, and land utilization, reflecting a relatively well-developed infrastructure and more modernized agricultural practices. In contrast, Melaka recorded the lowest FAI score, pointing to significant gaps in production capacity and resource utilization. The national composite score of 25, which falls within the high availability category, indicates that while Malaysia as a whole has a solid foundation for rice availability, substantial inter-state variation still exists and requires targeted policy responses.

The findings also highlight critical issues that continue to hinder optimal performance in several regions. Underutilized agricultural land and the continued reliance on traditional farming methods are major constraints that prevent states from realizing their full production potential. These inefficiencies not only limit yield but also contribute to food insecurity risks in the event of supply chain disruptions or environmental shocks. The results suggest a pressing need for integrated strategies that promote land optimization, expand mechanization, and reduce post-harvest losses.

Beyond its immediate application, this study lays important groundwork for the future of food security monitoring in Malaysia. The FAI offers a replicable and adaptable model that can serve as the basis for a fully localized, national Food Security Index. Such an index would be invaluable for streamlining policy formulation and enforcement, enabling more responsive and geographically targeted interventions. By adopting this localized approach, Malaysia will be better equipped to ensure sustainable food security, reduce dependency on imports, and respond proactively to emerging challenges in the agro-food sector.

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